reaction $CO_2+C=CO+CO$ shows that out of two volumes of $CO_2$ we receive four volumes of CO, and it is accompanied with absorption of heat, which is determined by the fact that the combustion of one atomic weight of carbon develops 97 K (*i.e.* 97 great calorics, or 97,000 common ones), while the combustion of CO develops 68·4 K; the reaction is thus accompanied by the following thermal result: $97·0\,K-2\times68·4\,K=-39·8\,K$. The result $(97·0-68·4-68·4=-39·8\,K)$ is the same for the following reaction: $H_2O+C=CO+H_2$; and, if the combustion of hydrogen in the calorimeter were not accompanied by a formation of liquid water, it might be admitted that the combustion of CO and of $H_2$ develops the same amount of heat, which, however, is not the case.

After having shown how the conclusions on the heat of formation of hydrocarbons from hydrogen and coal, or diamond, are vitiated by not taking into account the heat developed, or absorbed, by physical and mechanical processes, and how M. Thomsen (*Berliner Berichte*, 1880, p. 1321) was brought to erroneous conclusions as to the structure of the molecule of coal and diamond, as well as to the structure of hydrocarbons; M. Mendeleef says:—"In using calorimetrical data of chemical reactions to judge of the variation of chemical energy in a reaction, it is necessary to free them from the influence of physical and mechanical processes which accompany the reaction. Of course, the relative influence of these secondary processes is not very great, as the chemical process is the most important one, especially in such energetic reactions as the combustion of hydrocarbons; but it is important, for strictly maintaining the principle itself of thermo-chemistry, always to apply this correction, as we always apply the correction for loss of weight in the air, especially when weighing gases." "Only in the gaseous state can we consider the thermal relations of bodies free from the influence of the modified internal work, as was well pointed out by Berthelot in the first chapters of his work: 'Essai de Mecanique chimique'; therefore, all comparisons must be made in the gaseous state, as well for the bodies entering into reaction, as for those which we receive. When the determination of the heat of combustion is made for sòlid or liquid bodies, we obviously must add the latent heat of evaporation (and liquefaction) of the body, and deduct the latent heat of evaporation of water. This last is well known, and for a molecular weight in grammes (18 grammes) of water, it is equal to about 10·7 K at the temperature of 15° to 20° Cels. As to the heat of evaporation of hydrocarbons, it is still not sufficiently known. But we know that the heat necessary for the evaporation of *molecular quantities* of different bodies comparatively volatile, varies from 4 K (as for $NH_3$ and $N_2O$) to 15 K (as for quicksilver and ethyl), and usually is between 6 K to 10 K." This correction not being very great, and the determinations of heat of combustion not being yet very accurate, Prof. Mendeleef takes, for those bodies whose heat of evaporation is not yet determined, an approximate correction. Another correction is that which results from changes of volume of combining bodies. The mechanical work which results from this increase or decrease of volume is not very great (0·57 K in most of the determinations of Thomsen), but always must be taken into account.

By applying these corrections, Prof. Mendeleef gives a new corrected table of heats of combustion of twenty different hydrocarbons, as well as the heats of formation of these bodies from $CH_4$, CO, and $CO_2$. The corrections are not insignificant, as, for instance, for hydrogen, $CH^4$, $C^2H^6$, $C^3H^8$, and $C^7H^{16}$, whose heats of combustion, as determined by Thomsen, Berthelot, and Loughinin, are respectively—68·4, 213·5, 373·5, 533·5, and 1137·4; the corrected figures, as given by M. Mendeleef, are—57·4, 192, 342, 492, and 1062.

## THE WEDGE PHOTOMETER[1]

MUCH attention has recently been directed to the use of a wedge of shade glass as a means of measuring the light of the stars. While it has been maintained by various writers that this device is not a new one, the credit for its introduction as a practical method of stellar photometry seems clearly to belong to Prof. Pritchard, director of the University Observatory, Oxford. Various theoretical objections have been offered to this photometer, and numerous sources of error suggested. Prof. Pritchard has made the best possible reply to these criticisms by measuring a number of stars, and showing that his results agreed very closely with those obtained elsewhere by wholly different methods. His instrument consists of a wedge of shade glass of a neutral tint inserted in the field of the telescope, and movable so that a star may be viewed through the thicker or thinner portions at will. The exact position is indicated by means of a scale. The light of different stars is measured by bringing them in turn to the centre of the field, and moving the wedge from the thin towards the thick end until the star disappears. The exact point of disappearance is then read by the scale. The stars must always be kept in the same part of the field, or the readings will not be comparable. By a long wedge the error from this source will be reduced. A second wedge in the reversed position will render the absorption uniform throughout the field. Instead of keeping the star in the same place by means of clockwork, the edges of the wedge may be placed parallel to the path of the star, when the effect of its motion will be insensible. To obtain the best results, the work should be made purely differential, that is, frequent measures should be made of stars in the vicinity assumed as standards. Otherwise large errors may be committed, due to the varying sensitiveness of the eye, to the effect of moonlight, twilight, &c., and to various other causes.

A still further simplification of this photometer may be effected by substituting the diurnal motion of the earth for the scale as a measure of the position of the star as regards the wedge. It is only necessary to insert in the field a bar parallel to the edge of the wedge, and place it at right angles to the diurnal motion, so that a star in its transit across the field will pass behind the bar, and then undergo a continually increasing absorption as it passes towards the thicker portion of the wedge. It will thus grow fainter and fainter, until it finally disappears. It is now only necessary to measure the interval of time from the passage behind the bar until the star ceases to be visible, to determine the light. Moreover, all stars, whether bright or faint, will pass through the same phases, appearing in turn of the 10, 11, 12, &c., magnitude, until they finally become invisible. For stars of the same declination, the variation in the times will be proportioned to the variations in the thickness of the glass. But since the logarithm of the light transmitted varies as the thickness of the glass, and the stellar magnitude varies as the logarithm of the light, it follows that the time will vary as the magnitude. For stars of different declinations, the times of traversing a given distance will be proportional to the secant of the declination. If $\delta$, $\delta'$ are the declinations of two stars having magnitudes $m$ and $m'$, and $t$, $t'$ are the times between their transits over the bar and their disappearances, it follows that $m'-m=A\,(t\sec\delta-t'\sec\delta')$. For stars in the same declination calling $A\sec\delta=A'$ we have $m'-m=A'(t-t')$. Accordingly the distance of the bar from the edge of the wedge is unimportant, and, as in Prof. Pritchard's form of the instrument, it is only necessary to determine the value of a single constant, A. Various methods may be employed to determine this quantity. Prof. Pritchard has recommended reducing the aperture of the telescope. This method is open to the objection that the images are enlarged by diffraction when the aperture is diminished; constant errors may thus be introduced. Changing the aperture of a large telescope requires some time, and in the interval the sensibility of the eye may alter. These difficulties are avoided by the following method, which may be employed at any time. Cover the wedge with a diaphragm in which are two rectangular apertures, and place a uniformly illuminated surface behind it. Bring the two rectangles into contact by a double image prism, and measure their relative light by a Nicol. From the interval between the rectangles and the focal length of the telescope, the light in magnitudes corresponding to one second, or $A$ may be deduced. Perhaps the best method with a small telescope is to measure a large number of stars whose light has already been determined photometrically, and deduce $A$ from them.

The great advantage claimed for this form of wedge photometer is the simplicity of its construction, of the method of observing, and of the computations required to reduce the results. It may be easily transported and inserted in the field of any telescope like a ring micrometer. The time, if the observer is alone, may be taken by a chronograph or stop-watch. Great accuracy is not needed, since if ten seconds correspond to one magnitude, it will only be necessary to observe the time to single seconds. The best method is to employ an assistant to record and take the time from a chronometer or clock. If the stars are observed in zones, the transits over the bar serve to identify or

[1] By Prof. Edward C. Pickering. Presented May 10, 1882, at the American Academy of Arts and Sciences.

locate them, as well as to determine their light. A wedge inserted in the field of a transit instrument will permit the determination of the light of each star observed without interfering with the other portion of the observation. If the stars are all bright, time may be saved by dispensing with the thin portion of the wedge. In equatorial observations of asteroids the light may be measured photometrically with little additional expenditure of time. Perhaps the most useful application would be in the observation of zones. When the stars are somewhat scattered it would often happen that their light might be measured without any loss of time. By this instrument another field of usefulness is opened for the form of horizontal telescope advocated at a former meeting of this Academy (*Proc. Amer. Acad.* XVI. 364). Very perfect definition would not be required, since it would affect all the stars equally. To an amateur who would regard the complexity of an instrument as a serious objection to it, a means is now afforded of easily reducing his estimates of magnitude to an absolute system, and thus rendering them of real value.

## ELECTRICITY ON PIKE'S PEAK

THE following extracts relative to electricity, from Pike's Peak Monthly Abstract Journals, have been very kindly forwarded to us by General Hazen, the chief of the U.S. Signal Service, in accordance with a request made by us; we believe their publication will prove useful:—

*November* 23, 1873.—Atmospheric electricity manifested itself when line was broken by a crackling sound when binding screws were touched, and bright sparks drawn when storepipe was touched by my fingers.

*December* 7, 1873.—While line was broken I heard relay working; thinking line had been repaired, I hastened to adjust; received a severe shock, which convinced me that something stronger than our battery had charged the wire. Instrument cut out and lightning arrester screwed closer; in a few minutes a continuous stream of electricity passed between the two plates of the arrester with a loud noise, resembling that produced by a child's rattle; the fluid passed not in sparks, but in five or six continuous streams of light, as thick as a pencil lead, for two or three minutes at a time, with short intervals between; this continued for over an hour.

*December* 11, 1873.—On retiring I accidentally touched my drawers with two fingers of my hand, and drew two sparks from them. This is a common phenomenon after a snow-storm.

*January* 12, 1874.—Electric shocks.

*January* 24, 1874.—Received electric shock when opening stove door; as usual, it was not repeated.

*February* 25, 1874.—Same as January 24.

*May* 11, 1874.—During the entire day severe shocks were felt by any one touching the wire, and, the line being open, I could make plain signals with the key for about ten minutes.

*May* 20, 1874.— p.m., report could not be sent on account of atmospheric electricity (a thunder-storm).

*May* 21, 1874.—A flash of fire about two feet long leaped from arrester into the office, illuminating the rooms.

*May* 24, 1874.—A heavy thunder-storm passed slowly and directly over the peak; large sparks passed constantly through the arrester, while a strange crackling of the snow could be heard at times. While making the 2 p.m. observation, I heard the snow crackle as above mentioned, and felt at the same time on both temples, directly below the brass buttons of my cap, a pain as if from a slight burn. Putting up my hands, there was a sharp crack, and all pain had disappeared.

*May* 29, 1874.—At 6.20 a terrific storm commenced; blinding flashes of fire came into bath-rooms from the lightning-arrester and stoves; loud reports followed in rapid succession.

*July* 1, 1874.—A party of visitors were caught in a thunder-storm not far from the summit, and all state that they experienced peculiar burning sensations on face and hands, and heard a hissing sound proceeding from hair and whiskers.

*July* 9, 1874.—Heavy thunder-storm; large sparks passed through the arrester during its continuance. Mr. Copley telegraphed me this forenoon that he twice got knocked down, while repairing the line, by electric shocks.

*July* 14, 1874.—Thunder storm; lightning in beginning very severe. I received a very painful shock while working over the line by my fingers accidentally touching the metal of the key.

*July* 15, 1874.—Thunder heard in the distance throughout the evening, while strong ground currents passed through the arrester.

*July* 16, 1874.—Severe thunder-storm; sharp flashes and retorts came through the arrester to the terror of several lady visitors. Outside the building the electric effects were still more startling. The strange crackling of the hail mentioned before was again heard, and at the same time my whiskers became strongly electrified and repellant, and gave quite audible hissing sounds. In spite of the cap I wore my scalp appeared to be pricked with hundreds of red hot needles, and a burning sensation was felt on hands and face; several of the visitors who were outside had the same experience. A large dog who had followed his master out-doors became terrified, and made for the door with a pitiful howl. Lightning was seen in all directions in the evening, and ground currents passed incessantly through the arrester.

*July* 19, 1874.—A severe thunderstorm passed close over the Peak between 1.30 and 2.30 p.m.; lightning struck wire between 2nd and 3rd poles from the house; for a moment the wire resembled a rope of fire and vibrated violently for some minutes after the discharge—no damage done. Frequent loud discharges took place along the ground-wire between it and the rocks on which it rests. Hair and whiskers of anyone out-doors were electrified by each discharge.

*July* 21, 1874.—Heaviest thunderstorm of the season to-day; lightning terrific; constant crackling of fallen hail and peculiar clattering of the rocks as if shaken by subterranean convulsions, indicated the highly electrified state of the summit.

*August* 2, 1874.—I was obliged to keep the telegraph instruments cut out during the greater part of the day.

*August* 3, 1874.—The lightning rendered the line almost useless the entire afternoon; I got severely shocked when sending my report.

*August* 13, 1874.—Seventeen visitors to day; some of them made the ascent during a severe thunderstorm, and were much alarmed by the effects of the electricity upon their hair, one of them declared that his hair stood up so stiffly as to lift off his hat!

*October* 5, 1874.—Severe thunderstorm below summit in afternoon, observers severely shocked whilst calling Fenton at lower station.

*May* 22, 1875.—During storms to-day (hail and snow) electricity quite strong.

*May* 23, 1875.—Electricity strong at intervals during day and night.

*May* 24, 1875.—Hail from 3.55 p.m. till midnight, accompanied by very strong electricity, decreasing and increasing in intensity, a notable fact in all hail-storms.

*May* 25, 1875.—Electricity has shown itself nearly all day with variable force (hail frequent during the day).

*May* 29, 1875.—Hail about midday accompanied by electricity. In all our hailstorms the fall of hail entirely ceases for about a half a minute, following a heavy electric discharge, and the hailfall is considerably heavier for some little time following the discharge than before.

*July* 5, 1875.—Terrible electric storm in afternoon, at first its effects were felt only by the line, but about 2 p.m. its presence was evident everywhere on the summit; a constant stream of flame from the arrester; a constant crackling noise heard out of doors as though made by small pistols.

*May* 11, 1876.—During hailstorm at 7.30 I was compelled to cut out the wires owing to intensity, this I attempted with ungloved hand, and learned a lesson that was an impressive one; luckily I escaped with a slightly bruised head and a fearful scare.

*May* 25, 1874.—During a thunderstorm the wire outside, at two or three places, kept up a peculiar singing noise, resembling the singing cricket. I have previously noticed that the singing noise is never heard except when the atmosphere is very damp, and rain, hail, or snow is falling.

*June* 16, 1876.—At 5.20 p.m., as I was sitting on a rock near the monument, on the eastern edge of the summit, a blinding flash of lightning darted from a cloud seemingly not more than 500 feet north-east of me, and was accompanied by a sharp, quick, deafening report, and at the same time I felt the electricity dart through my entire person, jerking my extremities together as though by a most violent convulsion, and leaving tingling sensations in them for a quarter of an hour afterwards. Straine, who was sowing wood in the shed at the time received a similarly violent shock, and says that a ball of lightning ap-